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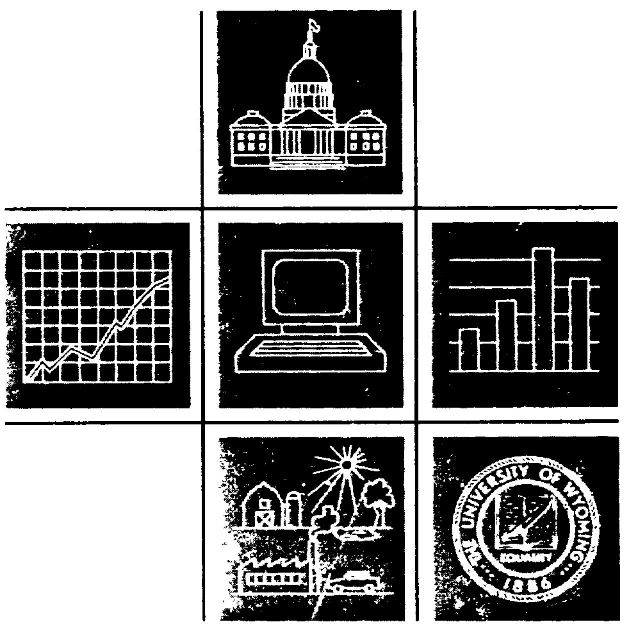

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Volume IV

Valuing Safety: Two Approaches

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EXPERIMENTAL METHODS FOR ASSESSING ENVIRONMENTAL BENEFITS

Volume IV

Valuing Safety: Two Approaches

by

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CHAPTER 1

INTRODUCTION

Valuing life is controversial and problematic. Much of the dispute concerning what role the economist should play in this matter stems from our reluctance to trade dollars for lives. Death is certainly unique--the ultimate irreversibility. To put an objective value on the anxiety, grief, and mystery that surrounds it is obviously beyond the competence of the economist. But it is just this mystical characteristic of death that binds most people in one common desire: "We nearly all want all lives extended and are probably willing to pay for it."[1]

Viscusi (1978b) summarizes the controversial nature of "valuing life" as follows:

> Ignoring the issue of valuation of life and limb may circumvent the problem of offending people's sensitivities by making the trade-offs explicit. But at the same time it may be very costly in that it sacrifices lives that could have been improved or saved by a more systematic allocation process. An important issue for society as a whole, and one that many people are unwilling to face, is whether lives will be sacrificed in an effort to maintain the illusion that we will not trade off lives for dollars.

The idea of valuing life is more palatable when put in proper perspective. It is not the worth of a particular human being that is at issue, but the value of preventing a "statistical death." Relevant preferences to be taken into account are not those for avoiding certain death, but rather those for avoiding a small probability of death. For economic policy the question is then asked to what extent should resources be devoted to programs which reduce the probability of death from a specific cause within a specific group of people. In order to assess the benefits of such programs, policymakers are forced to place a value on an expected life saved. The concept of expectations removes the mysterious, personal nature of the problem. No one within a specific group expects to die, but each possesses an intuitive feeling towards the risks he faces, and it may be worthwhile to reduce such risks.

The "good" which is to be valued is safety and it comes in the form of a reduction in the risk of death. Many government programs have been implemented which attempt to reduce the risks we face. These efforts have led to safety regulations affecting nuclear reactors, automobiles, hazardous wastes, food additives, and the like. Such regulations decrease the health risks faced by individuals, and prove beneficial by making our lives safer. In order to weigh these benefits against the costs of regulation, a value must be placed on reducing risk. This area of concern is referred to as the economics of safety.

If we view the economics of safety as valuing reductions in risk, rather than measuring the worth of a particular individual, our aversion towards trading dollars for safety may be lessened. A certain reluctance, however, persists and this is better understood after reviewing early attempts at measuring the value of safety.

Early work by economists exclusively dealt with the problem of valuing safety by attempting to place a monetary value on human life. Such efforts gave economists a "bad name" since it is often felt that "if additional expenditures can save lives we will spare no expense in doing so."[2] This precept is plausible in the case of specific individuals. Understandably, parents of a young tumor victim would be upset with an economist's attempt at placing a value on having the tumor be benign.

Though possibly offensive to some, quantification of the value of a human life is not a new concept. Dublin and Lotka (1946) have traced this valuation attempt to ancient times in which the valuation of a slave's 1' "made possible the enduring monuments in stone raised by the Pharoahs."[3] Anglo-Saxon law required that a value be placed on every free man's life, called wergild, for establishing compensation in cases of homicide.[4]

The idea that one can place a dollar value on human life has outlived these early civilizations. It manifests itself today in the form of the so-called human-capital approach. This widely accepted procedure for imputing a price on an expected change in mortality, equates the value of a person's life to expected discounted future earnings. Thus, the cost of a death is the expected loss in earned income. Implicit in this method is the value judgment that an individual is "worth" what he contributes to GNP. Further, for earnings to reflect this "value added" it is assumed that wages are equated to marginal product.

Originally the human-capital procedure was used to estimate optimal levels of life insurance. Later, it was utilized as a means of measuring economic losses from accidents and illnesses. Out of the latter application, the human-capital approach emerged as a convenient way to measure the benefits from life-saving programs. Despite strong criticisms based both on ethical and economic theoretical grounds, this approach still remains popular for policy purposes because of its appealing actuarial properties.[5]

Ethical objections to the human-capital approach cut deeper than the common negative reaction to placing a monetary value on life. Even if such an evaluation were acceptable, the human-capital method would value a retired autoworker's life or that of someone's grandmother at zero since such individuals have no future or current earnings. Such an approach ignores an individual's personal desire to live, and disregards the value an individual would attach to the opportunity of living a longer life. This latter point is crucial. It is the crux of why the "human-capital" approach, in spite of the label, has never been a salient component of human-capital theory.[6]

The reluctance of human capital theorists to accept this approach is due to the lack of a conceptual link between an individual's future earnings and willingness to pay for increased life expectancy. Linnerooth (1979), in reviewing the value of life models, concludes that "... there are no theoretical grounds for establishing an empirically useful relationship between the value, in the form of the Hicksian compensating variations in wealth [i.e., willingness to pay], of current period changes in a person's risk of death and his lifetime earnings."[7] Mishan (1971) points out that,

> If the j^{th} pesson is made better off, a compensating variation (CV) measures the full extent of his improvement, this CV being the maximum sum V_j he will pay rather than forego the project,--the sum being prefixed with a positive sign.--If the j^{th} person is made worse off by the introduction of the project, his CV measures the full decline in welfare as a minimal sum V_j he will accept to put up with the project, this sum being prefixed with a negative sign. [If] the algebraic sum of all n individual CV's is positive - there is a potential pareto improvement, its positive value being interpreted as the excess benefits over costs arising from the introduction of the project. (p. 692)

If the human-capital approach bears no relationship to an individual's willingness to pay for a reduced risk of death, then for economic purposes it is a useless concept. On the other hand, a willingness to pay measure of the value of life is compatible with economic efficiency and is perhaps more ethically acceptable. As Schulze and Kneese (1981) point out, "the economist's notion that individuals do voluntarily trade off safety for monetary compensation in no way attempts to value life." Rather, a willingness to pay measure estimates the maximum amount individuals would voluntarily give up in wealth in order to reduce a small risk of death by a small amount. When aggregated across many people, this gives a marginal value of safety (MVS) for preventing a statistical death. MVS, therefore, does not attempt to establish a value on a particular human life, but instead measures the benefits of preventing a statistical death. In light of the ethical and economic advantages of using the willingness to pay notion, this research will adopt the MVS concept for evaluating the benefits of life-saving programs.

The idea that benefits from life-saving programs should be based on MVS was first noted by Mishan (1971) and Schelling (1968). It is currently the framework within which all the principal theoretical economic research into the "value of life" operates.[8] Research of this type attempts to derive a demand for safety. Since many types of safety are public in nature, justification for government regulation rests in the theory of public goods. Further, since this issue is probabilistic in nature, the theoretical underpinnings lie in the expected utility model.

With the adoption of MVS, the controversial nature clouding this area of economics has subsided.[9] Gone, however, is the straightforward calculus inherent in the human-capital approach, though there has been a recent attempt (Arthur, 1984) to develop a method for valuing lives that is based on welfare theory yet has the desirable actuarial properties of the human capital approach. MVS calculations are much more problematic. The purpose of this research is to isolate the major problems inherent in the MVS and add to the body of literature which addresses them.

Five major areas of concern are confronted in this research effort. They are: (1) alternative methods for obtaining MVS measures, (2) the problem of measuring risk, (3) the divergence between willingness to pay (WTP) and willingness to accept (WTA) measures, (4) the determinants of the demand for safety, and (5) the so-called failure of the expected utility model.

1.1 ALTERNATIVE METHODS FOR OBTAINING MVS MEASURES

There are three methods which have been commonly used to obtain an MVS measure: the hedonic price method (HPM), the direct cost method (DCM) and the contingent valuation method (CVM). The HPM involves regressing the wage rate of a particular job on a vector of worker and job characteristics. Included in the latter is the job-related risk of death. The coefficient on risk is interpreted as a market risk premium and from this an MVS measure is obtained. The DCM, on the other hand, is based on examining the consumption and use of safety items such as smoke alarms and seat belts. The CVM utilizes surveys which ask the respondent directly his willingness to pay for a reduction in risk contingent on the existence of such a market for risk.

In the safety literature, estimates of the value of life based on all three methods have been compared (Blomquist, 1982). However, to date no study has based these comparisons on the same sample. Making such a comparison between the HPM and CVM is a major purpose of this report.

1.2 THE PROBLEM OF MEASURING RISK

As will be shown, risk measures generally used in MVS studies are suspect. Hedonic studies, in particular, purport to be measuring actual levels of job-related risks. Due to data limitations, however, such a goal is not realized. Further, even if such a measure existed, individuals accept risk on the basis of their perceptions (i.e., "perceived risk"). If we accept the proposition that the worth of safety programs, indeed any economic good, should be based on subjective preferences, then perceived risk is the ideal measure.

The psychological literature reveals that individuals have problems perceiving actual risk, yet MVS studies typically assume that people correctly calculate actual probabilities of death. This explains the persistent use of "actual risk" measures in these studies.

1.3 DIVERGENCIES BETWEEN WTP AND WTA

Willig (1976) makes the theoretical case that WTP and WTA measures should be similar. Empiric studies, however, have revealed the two to be significantly different.[10] This difference has not been adequately explained in the literature. In the area of safety, two possible explanations for these discrepancies are offered: (1) individuals behave differently towards gains in wealth than they do towards losses, and (2) individuals value voluntary and involuntary types of risk differently.

1.4 THE DETERMINANTS OF THE DEMAND FOR SAFETY

The amount an individual is willing to pay for reductions in risk depends on such characteristics as age, sex, relative levels of risk aversion, initial levels of risk, and income endowments. Since these characteristics vary across members of the population, one would expect their marginal values for safety to differ; therefore, it would not be of much use to derive a single number for the value of an expected life saved. Rather, it would be more useful to isolate the group that is to be affected, characterize that group's socio-economic make up and, after estimating how MVS varies with these characteristics, determine which MVS measure(s) is(are) appropriate. In light of this, MVS schedules may be more useful than trying to estimate a single elusive number.

1.5 FAILURE OF THE EXPECTED UTILITY MODEL

Schoemaker (1982) suggests that, for small probabilities of catastrophic events, the expected utility model (EU) fails as a device for describing or predicting human behavior. The p psychological literature has also attacked the assumptions underlying EU.[11] Yet, more recent studies have shown EU to work well.[12] Since MVS is built on the expected utility framework, these concerns require discussion.

In Chapter 2, these five issues are discussed in detail along with other relevant topics from the safety literature. Chapter 3 develops an intertemporal expected utility model of career choices where different jobs are characterized by their levels of risk. In this model, an MVS measure is obtained and a hypothesis that the market does not correctly compensate individuals for the risk they face on the job is developed. Existence of such a "wedge" is tested by comparing CVM and hedonic MVS estimates of the MVS obtained from the same sample.

A survey was conducted for the purpose of collecting data on (1) individuals' perceptions of their job-related risks, (2) WTP and WTA measures for hypothetical changes in these risks, and (3) socio-economic characteristics for the purpose of estimating a hedonic wage equation. The survey methodology and sample design are discussed in Chapter 4. Finally, in Chapter 5, the results of this survey are reported, the aforementioned hypothesis is tested, and a direct comparison of the contingent valuation and hedonic methods is made.

REFERENCES

1. Schelling (1968) p. 129.
2. Viscusi (1978b) p. 379.
3. Dublin and Lotka (1946).
4. Pollock and Maitland (1968) p. 47.
5. Linnerooth (1979) pp. 52-3.
6. Viscusi (1978b) p. 361.
7. Linnerooth (1979) p. 71.
8. Viscusi (1978b) p. 361
9. It should be pointed out that the MVS measure still converts changes in risk of death into dollars. Although this procedure places a dollar value on a statistical life rather than a specific life, some may still have ethical problems with it.
10. Cummings, Brookshire and Schulze (1984) p. 42.
11. Kahneman and Tversky (1979).
12. Brookshire, Thayer, Tschirhart and Schulze (1985).

CHAPTER 2

MARGINAL VALUE OF SAFETY ESTIMATES: A SURVEY

Through the insight of economists such as Mishan (1971) economic theory now embraces the theoretically correct willingness-to-pay measure of the value of life. This approach is more ethically acceptable than the human capital approach because it values small reductions in the risk of death rather than attempting to put a value on an individual human life. The relative ease of human-capital calculations, however, has lead to a persistent use of this approach for policy purposes. As a result, there is continued public disdain aimed at economists because it is perceived that the worth of an individual life is the object of analysis. This perception, however, may lessen with the refinement of marginal value of safety (MVS) estimates of the "value of life."

2.1 THE THEORETICAL STRUCTURE OF MVS

In theory, the MVS idea is straightforward. For potential reductions in risk it is merely an individual's maximum willingness to give up wealth $\Delta WLTH$, for a small change in risk, $\Delta\pi$, holding the initial level of utility, $\bar{U}$, constant. In general we say that:

$$MVS = \left.\frac{\Delta WLTH}{\Delta\pi}\right|_{\bar{U}} \tag{1}$$

when $\Delta\pi < 0$, $\Delta WLTH$ measures willingness to pay (WTP) and when $\Delta\pi > 0$, $\Delta WLTH$ measures willingness to accept (WTA). MVS, therefore, measures the slope of an individual's indifference curve in risk-income space, and is merely a Hicksian compensating variation.

To illustrate how MVS can be used as a measure of benefits from environmental safety programs, consider a program that is expected to decrease the deaths, from exposure to a certain toxin, in a community of 1,000,000 people from ten to five. If the program is implemented, therefore, the expected number of lives saved is five with each person's risk of dying decreasing from 10/1,000,000 to 5/1,000,000 or $\Delta\pi = 5 \times 10^{-6}$. Suppose that each individual in the community is willing to pay ten dollars for his personal reduction in risk. Appealing to equation (1) then,

$$MVS = \frac{\Delta WLTH}{\Delta\pi} = \frac{10}{5 \times 10^{-6}} = \$2,000,000.$$

In this hypothetical situation the value per expected life saved is $2 million. With the total expected lives saved being five, expected life-saving benefits from this program are $10 million.

When the element of risk is introduced, the individual faces a world of uncertain outcomes. In such a world where the possibility of death is probabilistic in nature, the "true" compensation variation is more correctly measured within the framework of an expected utility model. Jones-Lee (1974) provides a simple single-period expected utility model in which there are only two states of the world - "life" and "death". His model is as follows:

$$E(U) = (1 - \pi)U(WLTH) + \pi D(WLTH) \tag{2}$$

where π is the probability of death, U(WLTH) is utility as a function of wealth WLTH, conditional upon the occurrence of the "life" state, while D(WLTH) is utility conditional upon the occurrence of the "death" state. Both U'(WLTH) and D'(WLTH) refer to first derivatives and are positive. E(U) is a von Neumann/Morgenstern expected utility function. Provided that the individual obeys a set of reasonable axioms,[1] he will act as if (2) is maximized.

Utility in death is usually referred to as bequest value. As Jones-Lee notes, the function D(WLTH) "... is not meant to imply that the individual is able to bequeath all of WLTH to his heirs but signifies merely that the bequeathable sum is related to current wealth." Therefore, it is assumed that the individual receives some utility from the knowledge that a portion of his current wealth will be left to his heirs if he dies.

Jones-Lee derives a Hicksian compensating variation by assuming that the individual initially faces a probability $\bar{\pi}(0 < \bar{\pi} < 1)$ of death and has some level of wealth $\overline{WLTH}$ (>0). He then proposes that the individual has an opportunity to reduce $\bar{\pi}$ to $\tilde{\pi}(<\bar{\pi})$ by forfeiting a positive amount, V, of his wealth. The maximum value for V is such that:

$$(1 - \tilde{\pi})U(\overline{WLTH} - V) + \tilde{\pi}D(\overline{WLTH} - V) = (1 - \bar{\pi})U(\overline{WLTH}) + \bar{\pi}D(\overline{WLTH}). \tag{3}$$

Differentiating (3) yields

$$\frac{\partial V}{\partial \tilde{\pi}} = \frac{U - D}{(1 - \tilde{\pi})U' + \tilde{\pi}D'} \tag{4}$$

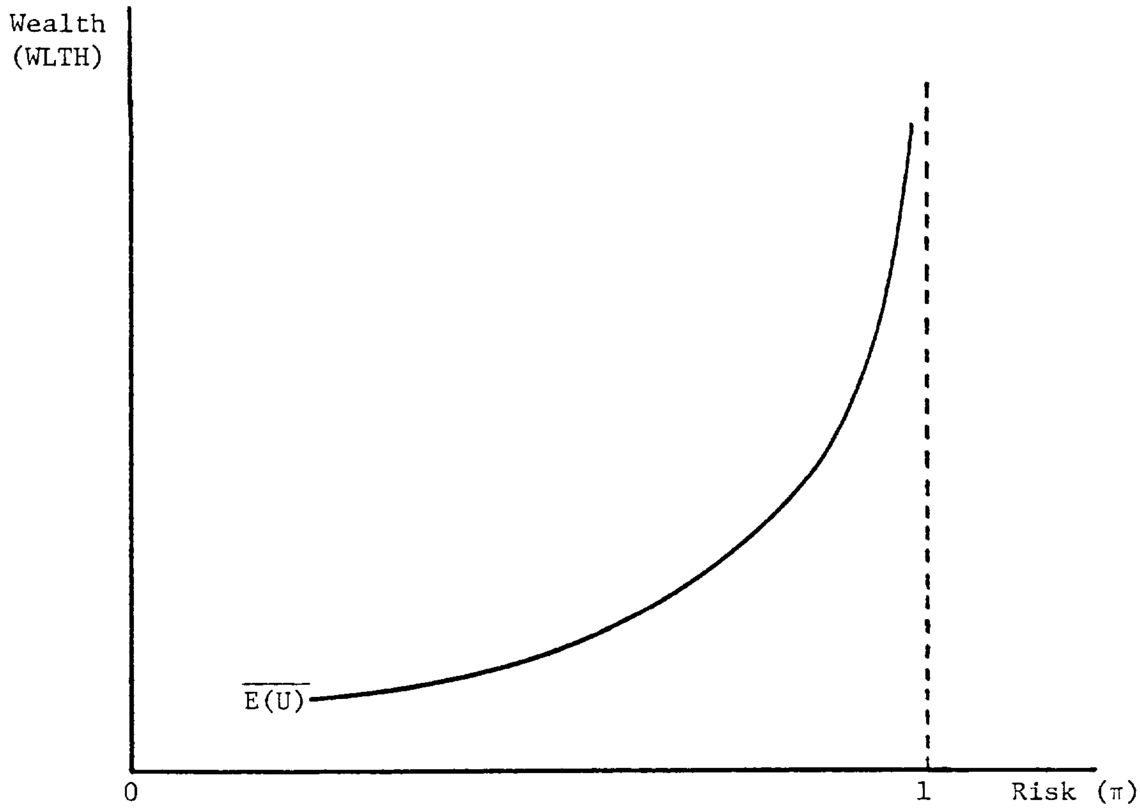
From equation (4) Jones-Lee concludes that: (1) the marginal value of a change in risk increases with both initial risk and initial wealth, (2) V is positive for values of $\tilde{\pi} < \bar{\pi}$ denoting the maximum WTP for reductions in risk, (increases in safety), and (3) V is negative for values of $\tilde{\pi} > \bar{\pi}$ denoting the minimum WTA for increases in risk (decreases in safety).

Jones-Lee's first point is perhaps clarified by deriving MVS in a slightly different manner. First, if we assume utility in death to be substantially small, relative to utility in life, as to be approximately zero, (2) simplifies to

$$E(U) = (1 - \pi)U(WLTH). \tag{5}$$

Totally differentiating (5) with respect to π and WLTH and holding E(U) constant yields:

Figure 2.1: Indifference Curve for Wealth and Risk



$$\left.\frac{dWLTH}{d\pi}\right|_{\overline{E(U)}} = \frac{U(WLTH)}{(1 - \pi)U'(WLTH)} = MVS. \tag{6}$$

Note that for $U''(WLTH) < 0$, as π approaches one, or as WLTH approaches infinity, MVS approaches infinity. Again, (6) describes the slope of an individual's indifference curve when utility is uncertain and in the absence of a bequeathment motive. Figure 2.1 shows a graph of such a level of expected utility with expected utility levels increasing as we move upward and to the left.

Because MVS approaches infinity as π approaches one, there is no compensation adequate for the individual to accept a probability of death equal to one. For small levels in risk, however, MVS is small. This is the situation facing individuals for most environmental safety programs; therefore, for most relevant economic analysis the extreme upper end of Figure 2.1 is meaningless.

Another important determinant of the MVS is an individual's level of risk aversion. Economists generally assume individuals exhibit risk-averse behavior.[2] If a certain outcome is preferred to a gamble with an equal or greater expected payoff, then a "risk-averse" choice is made. Bernoulli (1899) originally explained this by suggesting that individuals do not maximize expected wealth but rather maximize expected utility. A "risk-loving" individual also maximizes expected utility but does so by rejecting a certain outcome in favor of a gamble with an equal or lower expected payoff.

Both types of behavior are described in Figures 2.2.1 and 2.2.2. Consider three options: (A) a certain outcome, $WLTH_A$, of receiving \$50, (B) a gamble whose expected outcome, $E(WLTH_B)$, is \$60 (e.g., a gamble with a 60 percent chance of winning \$100 and a 40 percent chance of winning nothing) and (C) a gamble whose expected outcome, $E(WLTH_C)$, is \$40 (e.g., a gamble with a 40 percent chance of winning \$100 and a 60 percent chance of winning nothing). Figure 2.2.1 shows a risk-averse individual described by the concave utility function ODE while Figure 2.2.2 shows a risk-loving individual described by the convex utility function OIH. Given a choice between options A or B, the risk-averse individual maximizes expected utility by choosing the certain outcome, A, even though gamble B affords a higher expected payoff.

On the other hand, given a choice between options A or C, the risk-loving individual maximizes expected utility by opting for gamble C, even though the certain outcome, A, affords a higher level of potential wealth.

To examine how preferences towards risk affect safety evaluations, let the function U(WLTH), in equation (5), take the specific form:

$$U(WLTH) = WLTH^{\eta}. \tag{7}$$

The parameter η can be interpreted as a measure of the individual's attitude towards risk with $0 < \eta < 1$ implying risk aversion, $\eta = 1$ implying

Figure 2.2.1: Utility Function for a
Risk Averse Individual

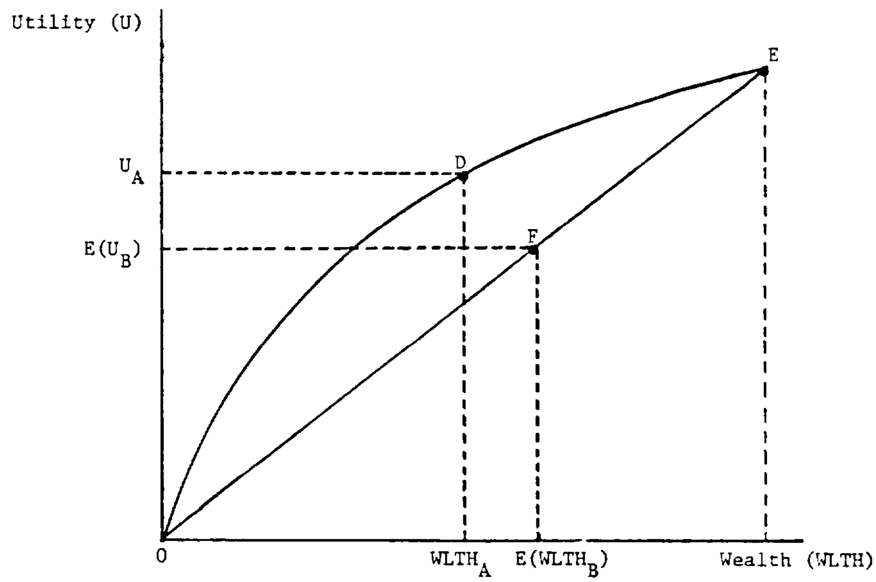
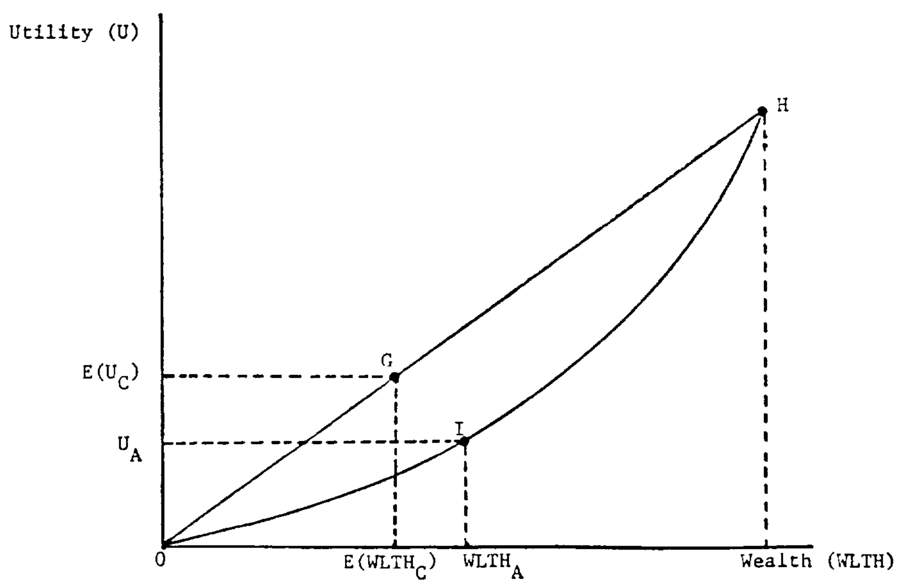


Figure 2.2.2: Utility Function for a
Risk Loving Individual



risk neutrality, and $\eta > 1$ implying risk-loving behavior. The expression for MVS in equation (6) becomes

$$\frac{dWLTH}{d\pi}\bigg|_{\overline{E(U)}} = \frac{WLTH}{\eta(1-\pi)} = MVS \tag{8}$$

and

$$\frac{d^2WLTH}{d\pi^2}\bigg|_{\overline{E(U)}} = \frac{WLTH}{\eta(1-\pi)^2}\ . \tag{9}$$

Note first that for WLTH, η, $\pi > 0$ both (8) and (9) are strictly positive. Furthermore, as the individual becomes less risk averse (i.e. η increasing) MVS decreases for any level of wealth or risk.

Figure 2.3 shows the indifference curves of two different individuals individuals where $E(U)_1$ is a level of expected utility for a more risk averse individual while $E(U)_2$ describes an expected utility level for a less risk averse (or risk loving) individual. From equations (8) and (9) the following conclusions can be drawn: (1) the slope of an expected utility level curve is positive and convex to the origin, (2) the convexity of this curve is invariant to attitudes towards risk, and (3) as the individual becomes less risk averse (or more risk-loving) the expected utility level curves become more flat for a given level of wealth or risk.

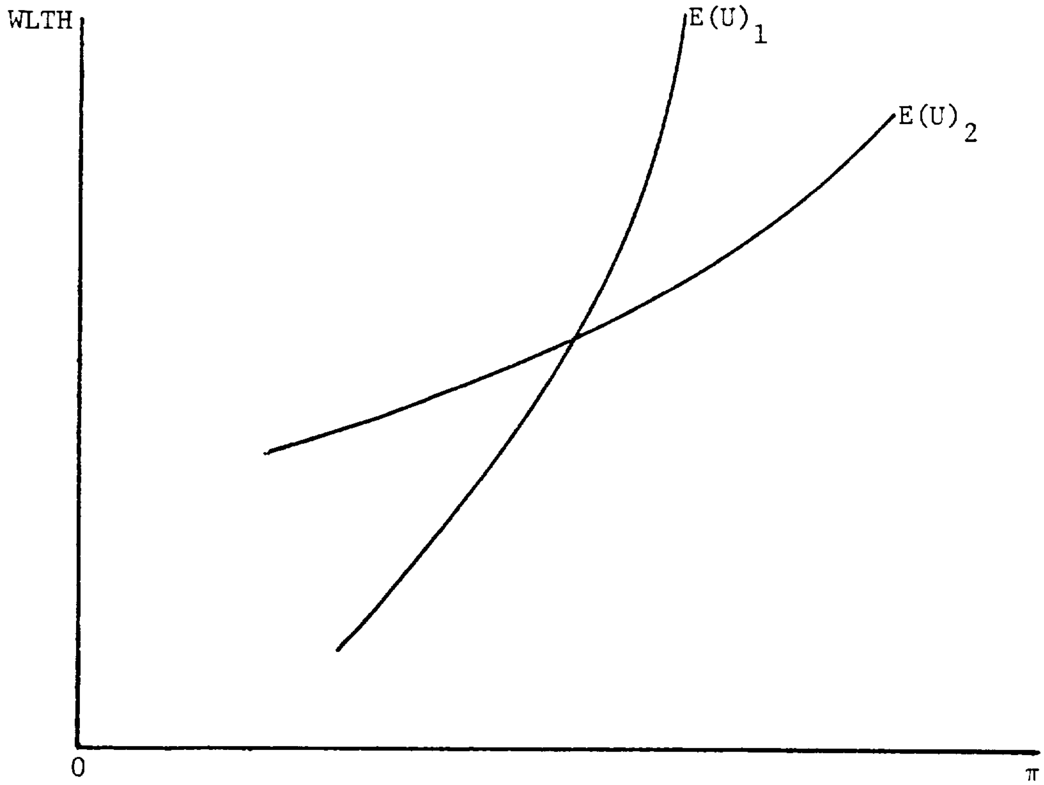
In summary, the basic theory behind an individual's willingness to pay for and marginal valuation of safety is a straightforward application of expected utility analysis. The process of obtaining information needed to measure an individual's MVS, however, is more problematic and involves different assumptions depending on the procedure used. In the next section, various methods for obtaining an MVS measure are discussed along with the theoretical assumptions of each and their empirical results found in the literature.

2.2 ALTERNATIVE METHODS FOR EVALUATING MVS

Studies which attempt to derive a MVS measure can be grouped into three major categories. First are the hedonic wage-risk studies which investigate tradeoffs in the labor market between job-related risks and wages. Contingent valuation studies, which directly ask individuals their willingness to pay for changes in safety, comprise the second category. The third group consists of consumer market studies that examine consumption and activity choices people make which affect their safety.

Rosen (1974) makes a strong case that it is difficult to infer risk valuation from consumption patterns. Such problems stem from deciding how preferences are split between the direct utility the activity renders and indirect longevity effects.[3] Due to these difficulties, few consumer market studies are found in the literature; therefore, this research will focus on the hedonic and contingent valuation methods. However, a couple examples of consumer market approaches are worth noting.

Figure 2.3: Indifference Curves for a Risk Averse and Risk Loving Individuals



Looking at the decision of an optimal highway speed, Ghosh et.al. (1975) attempted to measure MVS by looking at the trade off between saving time and the increased risk of a traffic fatality. In this study, the direct utility or (disutility) individuals derive from driving is ignored and is, therefore, an example of the problem Rosen eluded to above. Further, in assuming time saved is the only benefit received, the resulting MVS measures are perhaps lower bound estimates.[4]

Dardis (1980) utilized the price of smoke detectors as an MVS measure. While this may be correct for the marginal consumer, others would have been willing to pay an amount greater than the market price. This study, therefore, underestimates these non-marginal individuals' marginal values of safety.

Consumer market studies, in general, yield relatively low MVS estimates.[5] Violette and Chestnut (1983) attribute this to the apparent invalid assumptions made in these studies. This research will directly compare results obtained from using both the hedonic and contingent valuation methods; consequently, a detailed review of these two methods is warranted.

2.2.1. Hedonic Wage-Risk Studies: Hedonic Price Theory

Analyzing wage differentials across jobs with varying levels of risk is the primary method used for estimating safety valuations. Hedonic price theory forms the basis of these studies. According to this theory, market goods are described in terms of a vector of attributes, and a consumer's willingness to pay for a good is related to the sum of utilities he anticipates receiving from each of these characteristics. Hedonic price theory attempts to "impute" a price on these attributes for which there are no explicit markets.

Thaler and Rosen (1975) were the first to apply hedonic price theory to the labor market. In this situation, a worker is viewed as receiving a wage in exchange for supplying labor for a particular job represented by a set of job characteristics. Among these characteristics is the risk associated with working on the job.

While the market wage is represented by equilibrium between the supply and demand for the job in its entirety, an individual hedonic price measures the equilibrium premium a worker is to receive for a specific attribute of the job. The hedonic price for job-related risk is also based on both supply and demand factors.

On the supply side, it is hypothesized that workers will voluntarily accept a higher level of job-related risk for a higher wage. Demand is influenced by the fact that employers, faced with this positive relationship between wages and risk, have the option of making expenditures on safety equipment which decrease the level of job-related risk. As a result of job-safety improvement, workers will require a lower wage-risk premium. At the point where the marginal cost of safety improvements equals the marginal benefit of a reduced wage-risk premium, expenditures on safety equipment will cease. Hence, employers face a tradeoff between expenditures on wages and on safety equipment.

This trade-off faced by employers is described by an iso-profit curve in wage-risk space, while the trade off facing the worker is described by an indifference curve. Figure 2.4 shows these curves which are labeled ϕ and Θ respectively. In this figure, $W(\pi)$ denotes the market risk-related wage differential: also referred to as the hedonic wage-risk gradient. $W(\pi)$ describes a locus of tangencies between workers' indifference curves and employers' iso-profit contours and, therefore, corresponds to equality between a worker's marginal rate of substitution (between risk and wages) and an employer's marginal rate of technical substitution (described by the trade-off between expenditures on wages and safety improvements). The hedonic wage-risk gradient establishes the market equilibrium risk premium for various levels of risk.

There is an important point to note about $W(\pi)$. It cannot be used to estimate an individual's wage-risk indifference curve. Rather, by appealing to $W(\pi)$, only a specific point on the indifference curve associated with the market-clearing wage-risk level is known.[7] As such, hedonic wage-risk studies cannot directly estimate an individual's demand for safety.

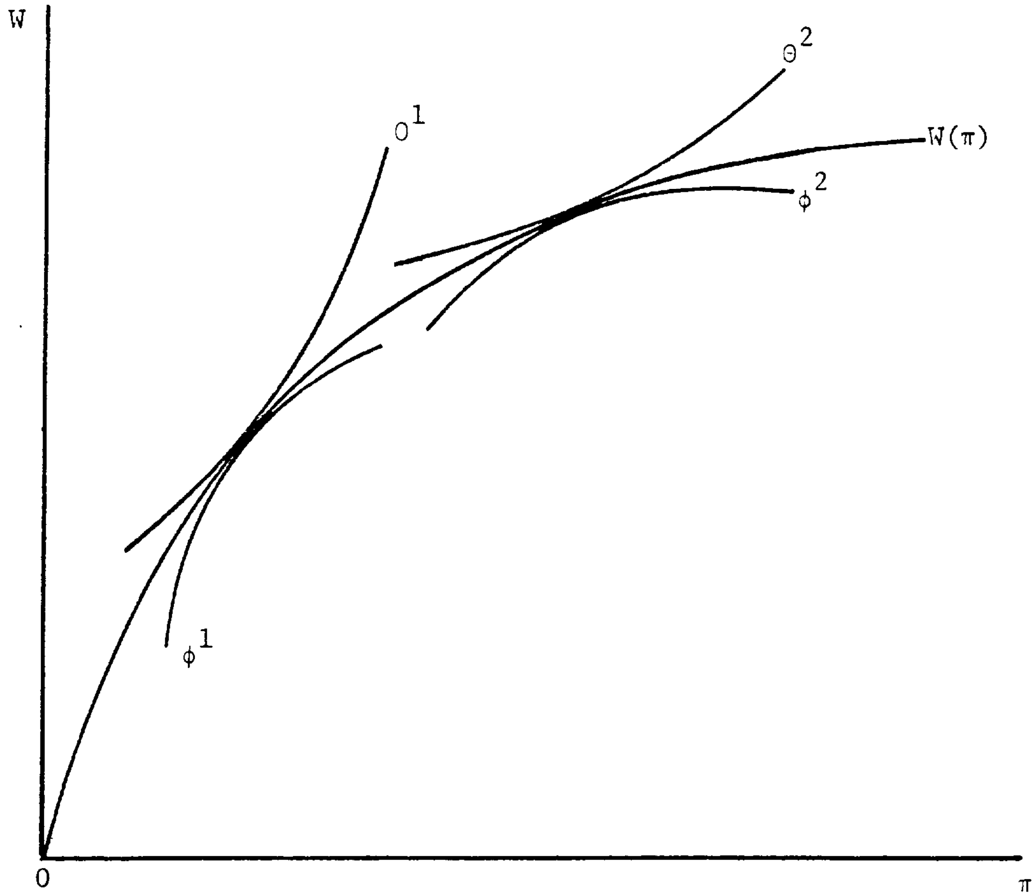
2.2.2 Hedonic Estimation Technique and Assumptions

According to hedonic wage-risk theory, market equilibrium occurs at a point of tangency along a worker's wage-risk indifference curve. Therefore, the rate at which the market compensates a worker for bearing job-related risk, described by the slope of $W(\pi)$, exactly equals his subjective MVS, as described by the slope of his indifference curve. If this theory holds, the technique for estimating an individual's MVS involves measuring how the labor market compensates workers for bearing risk.

Utilizing market data, wage-risk studies attempt to estimate $W(\pi)$ by regressing wage rates from various jobs on their associated job-characteristics. The coefficient on risk describes the rate at which the market compensates workers for taking on additional levels of risk. For a person's subjective MVS to be reflected by these market conditions, various important assumptions must be met. Especially enigmatic are the assumptions that: (1) the labor market operates freely and is in equilibrium and (2) workers know exactly how risky various potential jobs are.[8]

Violation of the first assumption will render MVS estimates which are biased.[9] An example of a market imperfection is labor unions. By using interaction terms between risk and union status, Olson (1981) found that union members receive higher wage-risk premiums than did non-union workers. Thus, the bargaining power of unions may push these premiums higher than would be expected under competitive conditions. An implication from Olson's analysis is that there may be two different markets at work--union and non union. Segmented markets are suggestive of barriers to entry since

Figure 2.4: Indifference and Isoprofit Curves



if labor was perfectly mobile across union and non-union markets, the difference in wage-risk premiums would disappear.

Another possible barrier to entry and exit emerges from the intertemporal expected utility model in Chapter 3. There it will be shown that the level of job-related risk a worker would optimally accept decreases through time; that is, individuals become more risk averse as they get older. The worker, however, cannot continually search for a lower risk job due to the transaction costs of re-locating and retaining: there are, in other words, barriers to exit. In this less than perfectly competitive situation it will be shown that hedonic wage-risk estimates of the MVS are biased downwards.

The assumption that workers can correctly calculate the actual risk level of potential jobs is necessary for observed (i.e. market) wage-risk premiums to reflect individuals' marginal values of safety.[10] Lichtenstein et al. (1978) show, however, that individuals reveal systematic errors in their perceptions of risk. If an individual's subjective MVS is based on perceived risk, utilizing actual risk measures (as is done in hedonic studies) amounts to an error in variables problem. MVS estimates from hedonic studies, therefore may, be inefficient and biased. The problem of measuring risk will be explained further in Section 2.3. The point here is that the assumption that perceptions of risk are identical to actual risk levels is, at best, extremely suspect.

2.2.3 Contingent Valuation Studies

Contingent valuation has been used to value a range of public and private goods. In valuing goods for which market prices are unavailable, prices must be imputed in order to measure the benefits these goods provide. In the previous section, it was shown that hedonic price theory, by imputing a price for individual characteristics of a good, attempts to place a value on specific attributes for which there is no explicit market. The contingent valuation method (CVM) is another approach to this problem.

The CVM utilizes surveys. For safety valuation, respondents are directly asked their willingness to pay (i.e., their "bids") for hypothetical reductions in risk, contingent on the existence of a market for safety. Randall et al. (1983) add that:

> contingent valuation devices involve asking individuals in survey or experimental settings, to reveal their personal valuations of increments (or decrements) in unpriced goods by using contingent markets... contingent markets elicit contingent choices.

By directly asking an individual's willingness to pay, the CVM elicits the tradeoffs he is willing to make between income and risk reduction. We observe individuals making these tradeoffs every day and it is "the challenge of the survey approaches . . . to elicit accurately the valuations on safety that are behind these kind of choices."[11]

Through the use of surveys, the CVM has the advantages of direct data collection and flexibility. For example, it was shown above that in order for hedonic techniques to yield true subjective evaluations, it must be assumed that people accurately perceive probabilities of injury or death. The CVM can be structured in such a way as to utilize subjective risk measures and thereby directly elicit the respondent's personal MVS. Therefore, the stringent assumptions required by the hedonic method are not necessary for contingent valuation studies. Considering the aforementioned psychological research that has been conducted on risk perceptions, use of methods may be the only viable approach for safety valuation. This point was made early on by Mishan (1971). He notes that:

> ...one can observe the quantities [people] choose, at least collectively, whereas one cannot generally observe their subjective valuations. In the circumstances, economists seriously concerned with coming to grips with the magnitudes may have to brave the disdain of their colleagues and consider the possibility that data yielded by surveys based on the questionnaire method are better than none... In the last resort, one could invoke contingency calculations.

If the CVM affords the economist the opportunity to directly obtain subjective evaluations, where does the "disdain" towards surveys stem from? Psychological research generally supports the hypothesis that surveys which attempt to elicit opinions or attitudes do poorly in predicting behavior. This criticism, however, cannot necessarily be directed at the CVM since respondents are not asked for their opinions but rather their contingent valuation.[12] However, as Cummings, Brookshire, and Schulze (1984) point out, "a large part of the criticisms of the CVM in terms of reliability or accuracy arise from the hypothetical nature of the CVM."

Many economists (e.g. Schelling, 1968; Viscusi, 1978b; Feenburg and Mills, 1980) feel that since the CVM asks hypothetical questions, respondents have no incentive to tell the truth; that is, responses obtained from a survey will be biased from an individual's "true" willingness to pay. Freeman (1979) explains the source of "hypothetical bias" to be as follows:

> In the real world, an individual who takes an action inconsistent with his basic preference, perhaps by mistake, incurs a cost or a loss of utility. In the [CVM]... there is no cost to being wrong, and therefore, no incentive to undertake the mental effort to be accurate.

Ask a hypothetical question, it is felt, and you get a hypothetical answer.[13]

A second form of bias in the CVM is referred to as strategic bias. Rowe et al. (1980) defines strategic bias as "an attempt by any individual to influence the outcome or results by not revealing a true evaluation." If the respondent believes that the results of the survey will affect government policy, such an incentive could be strong. Empirical evidence on strategic bias suggests, however, that the hypothetical nature of surveys can alleviate incentives for strategic behavior.[14] Cummings, Brookshire, and Schulze are quick to point out that this places the researcher in a "potential dilemma: The more hypothetical the question, the less the incentive for strategic behavior but, also, the less the incentive for accurate responses."

There is yet another type of dilemma inherent in the CVM. Since contingent valuation techniques involve setting up a hypothetical market it is imperative that the survey design include relevant information regarding that "market." However, as Fischhoff et al. (1982) point out, the experimental setting is an important determinant of the survey results. To quote Fischhoff et al.:

> The fact that one has a question is no guarantee that others have answers, or even that they have devoted any prior thought to the matter. When one must have an answer . . . there may be no substitute for an elicitation procedure that educates respondents about how they might look at the question. The possibilities for manipulation in such interviews are obvious. However, one cannot claim to be serving respondents' best interests by asking a question that only touches on one facet of a complex and incompletely formulated set of views.

Economists have discovered "information bias" to be both troublesome and difficult to define. A broad definition of information bias is given by Rowe et al. (1980) as "[a] potential set of biases induced by the test instrument, interviewee, or process, and their effects on the individual's responses." Potential sources of information bias include: (1) the vehicle to be used for collecting the bids, (2) the order in which the information is given, and (3) what information is given to the respondent. Economists (e.g., Rowe et al., 1980; Brookshire et al., 1981; Cronin, 1982) as well as psychologists (e.g., Lichtenstein et al., 1978; Fischhoff and MacGregor, 1980; Fischhoff et al., 1982) have found these sources of information bias to be present in survey methods.

While it is not the purpose of this research to resolve these problems of the CVM, they should be pointed out. Cummings et al., however, conclude that "there is reasonably compelling evidence that suggests the possibility of resolving most of the above-mentioned issues . . . . by thoughtful design of the CVM." In other words, ask a well constructed hypothetical question and people will try to give an honest answer.[15]

To summarize, the advantages of the CVM over the hedonic technique include: (1) the ability to directly obtain safety valuations without requiring individuals to correctly calculate probabilities of death or injury, (2) the flexibility of direct data collection, and (3) the lack of stringent theoretical assumptions. The disadvantages of the CVM stem from the problem of designing a survey which minimizes the hypothetical and information biases inherent in survey techniques.

2.2.4 Empirical Results Obtained from the Hedonic and CVM

Depending on the assumptions, procedures and data used, empirical estimates of the value of an expected life saved vary greatly from study to study. Estimates from hedonic methods range from $400,000 to $7.5 million while those from contingent valuation studies vary from $17,000 to $325 million.[16] An excellent summary of studies utilizing both the hedonic technique and the CVM is given by Violette and Chestnut (1983). While it would be redundant to reproduce their summary, a few major points will be made.

First, the hedonic wage-risk studies make inferences about safety valuation based on estimates of how the market compensates individuals for accepting job-related risk. These studies are based on the assumptions mentioned above and each study attempts to collect data on actual levels of job-related risk. Differences in MVS estimates from hedonic studies primarily stem from the various ways the risk data are obtained and the type of workers emphasized.

Most hedonic studies utilize data from either the Bureau of Labor Statistics (BLS) or a survey conducted by the Society of Actuaries. The large differences in MVS estimates among hedonic studies has been largely attributed to which of these two data sources are used.[17] The reasons for this are explained in the next section therefore this discussion is deferred until Section 2.3.

The choice of which workers to sample greatly affects the MVS estimates obtained. Thaler and Rosen (1975) based their study on a sample of very hazardous occupations and obtained relatively low value of life estimates --around $600,000 per expected life saved. Olson (1981) notes that "since the value of life declines as risk increases, [Thaler and Rosen] were dealing with the extreme tail of the work force's risk distribution." As suggested above, these workers may tend to be the least risk averse and, as a result, have lower valuations of safety. Using data on workers in relatively low risk jobs, on the other hand, Olson obtained larger MVS estimates of around $7 million.

The range of MVS estimates obtained from contingent valuation studies is much larger than that of hedonic approaches. Two reasons for this larger variation are, first, different types of risk are analyzed and, second, the survey designs employed vary greatly across studies. Examples of the different types of risk examined in contingent valuation studies include heart attack fatalities (Acton, 1973), airline accident fatalities (Jones-Lee, 1976), and nuclear plant accident injuries (Mulligan, 1977). Finally, a third reason for the wide variation in CVM estimates is that these studies were conducted during the early stages of developing this method. Presumably the same type of studies would yield closer results if done today, now that more is known about how to best apply the CVM.

That individuals reveal a disparity in their valuations for reductions in different types of risk is of no surprise to psychologists. Weinstein and Quinn (1983) suggest that such valuations depend on whether the risks of evaluation is ex ante or ex post. Starr (1969) notes that whether a risk is involuntary or voluntary affects safety valuations. Other studies conclude that people are willing to pay more for reductions in risk if the danger occurs in the form of a catastrophe (e.g., airline accidents) rather than if spread out over time (e.g., heart disease).[18] Therefore, it is not surprising that the use of different types of risk in the contingent valuation studies lead to a large range in MVS estimates.

Different survey designs found in the literature have varying degrees of the aforementioned biases and therefore their resulting MVS estimates will consequently differ. Moreover, Violette and Chestnut conclude that the majority of the contingent valuation attempts at valuing reductions in risk "could have benefited from the refinements in survey design that have been evolving in other areas of environmental quality valuations." Therefore, survey design is both a source of variation in MVS estimates and something which requires greater refinement.

2.2.5. Comparison Studies of the Hedonic and CVM

Because of the different types of risk measures used, it is impossible to directly compare the results from the hedonic and contingent valuation methods found in the literature. In Chapter 4, a survey design is discussed with this goal in mind. The emphasis there will be on perceived job-related risk.

In order to directly compare the two approaches, this survey was used to collect information on how risky individuals feel their jobs to be. This perceived risk measure was then used, along with socio-economic information collected from the survey, in order to estimate a hedonic wage-risk equation. In addition, the respondents were directly asked their willingness to pay for reductions in their job-related risk by one unit from their initial perceived level. In this way, the two approaches were directly compared.

In the next section some of the problems involved in obtaining a risk measure are discussed.

2.3 PROBLEMS OF MEASURING RISK

In order to measure individuals' safety valuations it is necessary to measure risk. Hedonic studies, for example, must measure job-related risk of death. At first glance this might appear to be quite easy since job-related risk of death is merely the frequency which workers die, per year, due to accidents and other stresses experienced on the job. Note that this frequency would include illnesses such as strokes and heart attacks suffered away from work but directly "caused" by the job. The more hazards associated with a particular job, the more risky that job is. Such objective probability figures will be referred to as the actual risk of job-related accidental death, π_a.

Let us assume initially that π_a is the ideal measure; an assumption made by the hedonic wage-risk studies. To accurately describe the actual level of risk a worker faces on the job, one would need a risk measure for each occupation within each specific industry. A welder on an assembly line, for example, does not face the same hazards as someone who welds ships: although both people share the same occupation. The available data, unfortunately, do not come in such detail. We can, however, use this "ideal" as a means to judge the data that are available.

Data on π_a which can be used come primarily from one of two sources--the Bureau of Labor Statistics (BLS) or the Society of Actuaries. Most hedonic wage-risk studies have utilized data from the BLS which provide average injury or death rates by industry.[19] However, because π_a is not the same across occupations within an industry, the use of these data introduces measurement error.[20] Utilizing BLS data, for example, would mean assigning a receptionist in the oil industry the same level of π_a as a "roughneck." This error-in-variables problem results in MVS estimates which are biased and inconsistent, the degree of each being related to the variance of the measurement error.[21] Some hedonic studies (e.g., Viscusi, 1978b) have attempted to reduce this problem by including dummy variables for occupation classes. The criticisms aimed at this data source, however, are still valid.

Thaler and Rosen's (1975) study attempted to avoid this problem of measurement error by obtaining risk of death data from the Society of Actuaries. These data measure the extra risk of insuring an individual in one of 37 narrowly defined and relatively hazardous occupations. In addition to the problems alluded to above of focusing on the least risk averse individuals, Thaler and Rosen's data introduced a form of measurement error. As Lipsey (1975) points out, this insurance risk reflects the death risks associated with an occupation and death risks associated with personal characteristics of the individuals in these occupations. According to these data, for example, a bartender has a level of π_a over four times as great as that of a fireman.[22] Clearly, these figures include factors other than just job-related risk. According to Violette and Chestnut (1983), "[t]he Society of Actuaries data used by Thaler and Rosen may have reduced one source of measurement error only to add another source of an unknown magnitude.'

Therefore, hedonic techniques, by incorrectly measuring π_a, introduce measurement error which yields MVS measures which are suspect. Moreover, even if a true measure of π_a could be obtained, there is compelling evidence that this is not the ideal measure to be used. Fischhoff et al. (1982) make a convincing argument that individuals have a problem calculating objective probabilities of risk of death. Their findings show that there is a systematic error in what individuals perceived the frequency of lethal events to be. Therefore, a person's perceived risk of job-related accidental death, π_p, is not equal to the actual level, π_a. Two implications fall from this observation: (1) workers voluntarily trade increase job-related risk for increased wages based on their perceptions of such risks thus forcing the market to make compensations based on π_p, and (2) benefits people receive from environmental programs which reduce risk, based on subjective evaluations of risk reduction, also stem from perceived risk. These implications suggest the "ideal" risk measure to be used is not π_a, but rather π_p. Therefore, by using π_a, even if measured correctly, another error in variables problem is introduced.

One could argue that if individuals misperceive risk, then why should policy be based on "bogus preferences"? Fromm (1968) perhaps epitomizes this school of thought by saying:

> [M]y own feeling is that society would be better advised to treat individual decisions in this area as imperfect and not rely on willingness to pay as the primary criterion for fixing the scope or magnitude of life-saving programs.

While Fromm suggests that government policy should be careful in adhering to the "anarchy of individual preferences," such an idea is primarily philosophical in nature. The question raised is whether individual preferences, "right" or "wrong," should prevail; or is it the role of the government to induce "correct" preferences on individuals.

Welfare economics argues that "people's subjective preferences of the worth of a thing must be counted."[23] If, for example, an individual living next to a nuclear power plant personally feels that his chance of dying from radiation is twice as high as it is in actuality, then his subjective willingness to pay for increased regulations will be relatively high. Government policy should be based on such willingness to pay measures because there is a personal reduction in anxiety and a greater sense of well-being which will be included in the benefits of such a policy. The fact that some may feel that the anxiety is based on false risk-calculations does not change the fact that he is willing to pay some amount based on personal subjective evaluations. Indeed, the fact that some people are willing to pay more than others for a roller-skating experience at Venice beach does not, at least in economic terms, make them incorrect or irrational. It does, however, reflect their subjective evaluations of the benefits of such an experience. Schelling (1968) perhaps put it best by saying:

> As an economist I have to keep reminding myself that consumer sovereignty is not just a metaphor and is not justified solely by reference to the unseen hand. It derives with even greater authority from another principle of about the same vintage, "no taxation without representation." Welfare economics establishes the convenience of consumer sovereignty and its compatibility with economic efficiency; the sovereignty itself is typically established by arms, martyrdom, boycott, or some principles held to be self-evident. And it includes the inalienable right of the consumer to make his own mistakes.

Arguments for utilizing perceived risk of death in methods which attempt to estimate a person's willingness to pay for safety are plentiful. The process of measuring perceived risk must involve some type of well-designed survey or laboratory experiment. As a result, the contingent valuation method, along with experimental economics, must play a larger role in the evaluation of risk reduction. To this end, a survey is described in Chapter 4 which attempts to measure perceived job-related risk of death.

There is yet another advantage that survey methods have over hedonic approaches: the potential of eliciting different willingness to pay estimates for different types of risk. As was mentioned above, psychologists suggest that individuals value reductions in different types of risk differently. If this is true, then the appropriateness of utilizing estimates of willingness to pay for reductions in job-related risk to measure benefits from reductions in environmental risk may be suspect. Survey methods may circumvent this problem by establishing hypothetical markets for different types of risk.

In the next section the large difference between willingness to pay (WTP) and willingness to accept (WTA) are discussed. Here it is suggested that different risk valuations can be partially explained as individuals' valuations of two different types of risk: voluntary and involuntary. Further, behavior differences toward gains and losses in wealth may also explain divergencies between WTP and WTA measures.

2.4 DIVERGENCIES BETWEEN WTP AND WTA

Changes in environmental commodities, such as safety, affect individual welfare and it is the attempt to measure these welfare changes which makes estimating the MVS important. In theory, changes in welfare can be defined in terms of compensating variation (CV) or equivalent variation (EV); both measure the area under the Hicksian compensated demand curve.[24] For quantity increases in an environmental "good," the CV measure denotes an individual's willingness to pay (WTP) while his willingness to accept (WTA) is described by the EV measure.

Appealing to equation (5) above, these measures of welfare change can be applied to environmental risk. WTP is described by the value of $\Delta WLTH_P$ which maintains the equality:

$$(1 - \pi^\circ)U(WLTH^\circ) = [1 - (\pi^\circ - \Delta\pi)]U(WLTH^\circ - \Delta WLTH_P) \qquad (10)$$

where π° and $WLTH^\circ$ are, respectively, initial levels of risk and wealth. WTA, on the other hand, is described by the value of $\Delta WLTH_A$ which maintains the equality:

$$(1 - \pi^\circ)U(WLTH^\circ) = [1 - (\pi^\circ + \Delta\pi)]U(WLTH^\circ + \Delta WLTH_A) \qquad (11)$$

Therefore, WTP is the maximum decrease in wealth, $\Delta WLTH_P$, the individual will voluntarily give up in order to receive a reduction in risk, $\Delta\pi$, and still maintain his initial level of expected utility. Conversely, WTA is the minimum level of compensation to wealth, $\Delta WLTH_A$, the individual must receive in order to voluntarily accept an increase in risk, $\Delta\pi$, and still maintain his initial level of expected utility.

It has long been felt the EV and CV measures of a welfare change will not be exactly the same except in the case where the demand for the good in question exhibits a zero income effect. Moreover, there is no theoretically decisive case which can be made for using one measure over the other.[25] Willig (1976), however, shows theoretically that, for price changes, differences in CV and EV measures, along with the observable consumer surplus measure, are negligible. According to Takayama (1982), the same holds true for changes in quantity. In theory, therefore, WTP and WTA measures should be approximately the same: implying that $\Delta WLTH_P$ in equation (10) should equal $\Delta WLTH_A$ in equation (11).

There is, however, strong empirical evidence that suggests WTP and WTA measures are significantly different. Table 2.1 shows the results from a number of studies which estimate both WTP and WTA measures for different environmental commodities other than environmental risk. These studies reveal WTA measures to be many times greater than the WTP counterpart. It is hypothesized, therefore, that the amount of compensation required for a one unit increase in risk may well be many times greater than what an individual would be willing to pay for a one unit reduction in risk. This hypothesis is tested in Chapter 5.

The large discrepancies between WTP and WTA estimates have not been adequately explained in the economics literature.[26] In the area of risk-evaluation two possible explanations for these discrepancies are offered: (1) individuals exhibit different behavior towards gains in wealth than they do towards losses, and (2) individuals respond differently towards voluntary versus involuntary types of risk.

2.4.1. Behavior Towards Gains and Losses in Wealth

Equation (10) above describes an individual's willingness to pay for a reduction in risk as the maximum loss in wealth he would voluntarily sustain such that the initial level of expected utility is unchanged. Figure 2.5 shows this situation. For simplicity it is assumed that utility in death is zero. Another way to view this is that no wealth, WLTH, is realized in the "death" state and that U(WLTH = 0) is zero.

In Figure 2.5, the individual's utility curve is described by the curve OBD. Here, initial wealth is labeled $WLTH^\circ$ while initial risk of death is π° = CD/OD = .35, and, therefore, the initial probability of life is $(1 - \pi^\circ)$ = OC/OD = .65. Since it is uncertain whether the individual will live to realize $WLTH^\circ$, expected wealth is $(1 - \pi^\circ)WLTH^\circ$ while expected utility, E(U), is described by $(1 - \pi^\circ)U(WLTH^\circ)$. If the individual is asked for his maximum willingness to pay in order to obtain a lower level of risk, π = AB/OB = .25, then by construction, $\Delta WLTH$ is the change in wealth which satisfies equation (10).

Further, assuming a concave utility function and appealing to equation (6), his MVS will fall from MVS" to MVS. That is, since $\pi^\circ > \pi$ and $WLTH^\circ > WLTH$:

TABLE 2.1

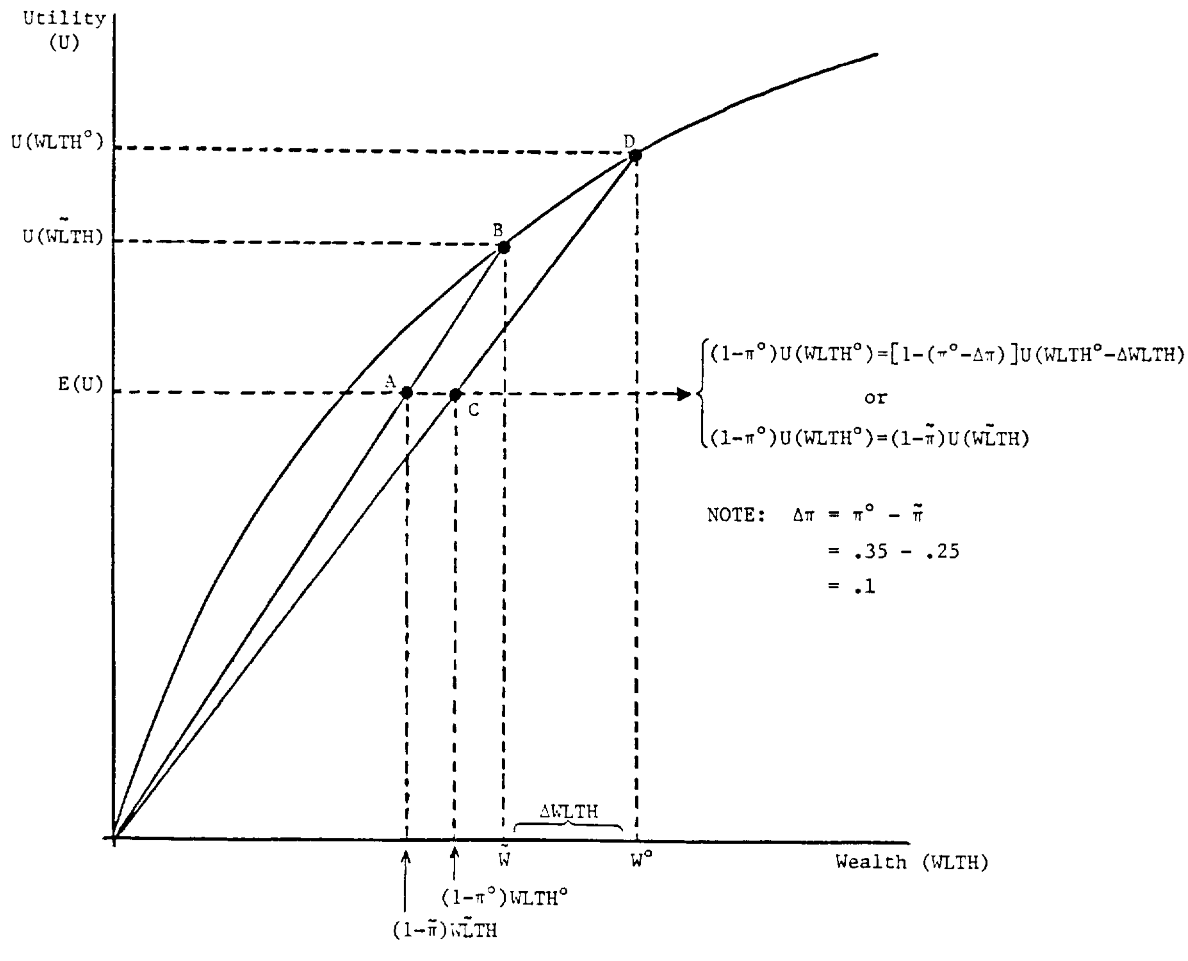
MEASURES OF WTP AND WTA[a]

Study	WTP	WTA
Hammack and Brown (1974)	$247.00	$1044.00
Banford, Knetsch, and Mouser 91977)	43.00	120.00
	22.00	93.00
Sinclair (1976)	35.00	100.00
Bishop and Heberlein (1979)	21.00	101.00
Brookshire, Randall, and Stoll (1980)	43.64	68.52
	54.07	142.60
	32.00	207.07
Rowe, d'Arge, and Brookshire (1980)	4.75	24.47
	6.54	71.44
	3.53	46.63
	6.85	113.68
Hovis, Coursey, and Schulze (1983)	2.50	9.50
	2.75	4.50
Knetsch and Sinden (1983)	1.28	5.18

[a]All figures are in year-of-study dollars.

SOURCE: Valuing Environmental Goods: A State of the Art Assessment of the Contingent Valuation Method. Cummings, R. G., Brookshire, D. S. and Schulze, W.D., Draft (May 1984).

Figure 2.5: Willingness to Pay for Reduced Risk



$$MVS^\circ = \frac{U(WLTH^\circ)}{(1 - \pi^\circ)U'(WLTH^\circ)} > \tilde{MVS} = \frac{U(\tilde{WLTH})}{(1 - \tilde{\pi})U'(\tilde{WLTH})} \tag{12}$$

Figure 2.5 also shows that if the above situation were reversed so that the initial level of wealth and risk were respectively $\tilde{\pi}$ and WITH, the compensation required to accept the higher level of risk, π°, is also AWLTH and his MVS will increase from MVS to MVS°. Within this theoretical construct, therefore, we would expect WTP and WTA to be the same.

One possible explanation for the fact that estimates of WTA have been shown to be much larger than those of WTP is that individuals tend to value gains to wealth (compensation for increases in risk) differently than losses in wealth (payment for reductions in risk). Kahneman and Tversky (1982) note that individuals are much more sensitive towards losses in wealth than they are towards gains in wealth.

The idea that people may value losses stronger than gains is suggestive of a tendency towards conservatism. The individual may simply lack the experience necessary to correctly calculate the resulting utility associated with changes in wealth from the norm. In this situation an individuals ex ante perceptions of what his utility will be from, say an increase in wealth, may differ from what it ends up being ex post. To compensate for what is essentially an exploration process, the individual may act conservatively by underestimating the potential gains and overestimating the potential losses in utility from respective increases and decreases in wealth.

Figure 2.6 describes such a situation. This figure shows the individual's initial level of risk and utility as being $WLTH^\circ$ and $U(WLTH^\circ)$ respectively while their utility function is described by the curve OAB.

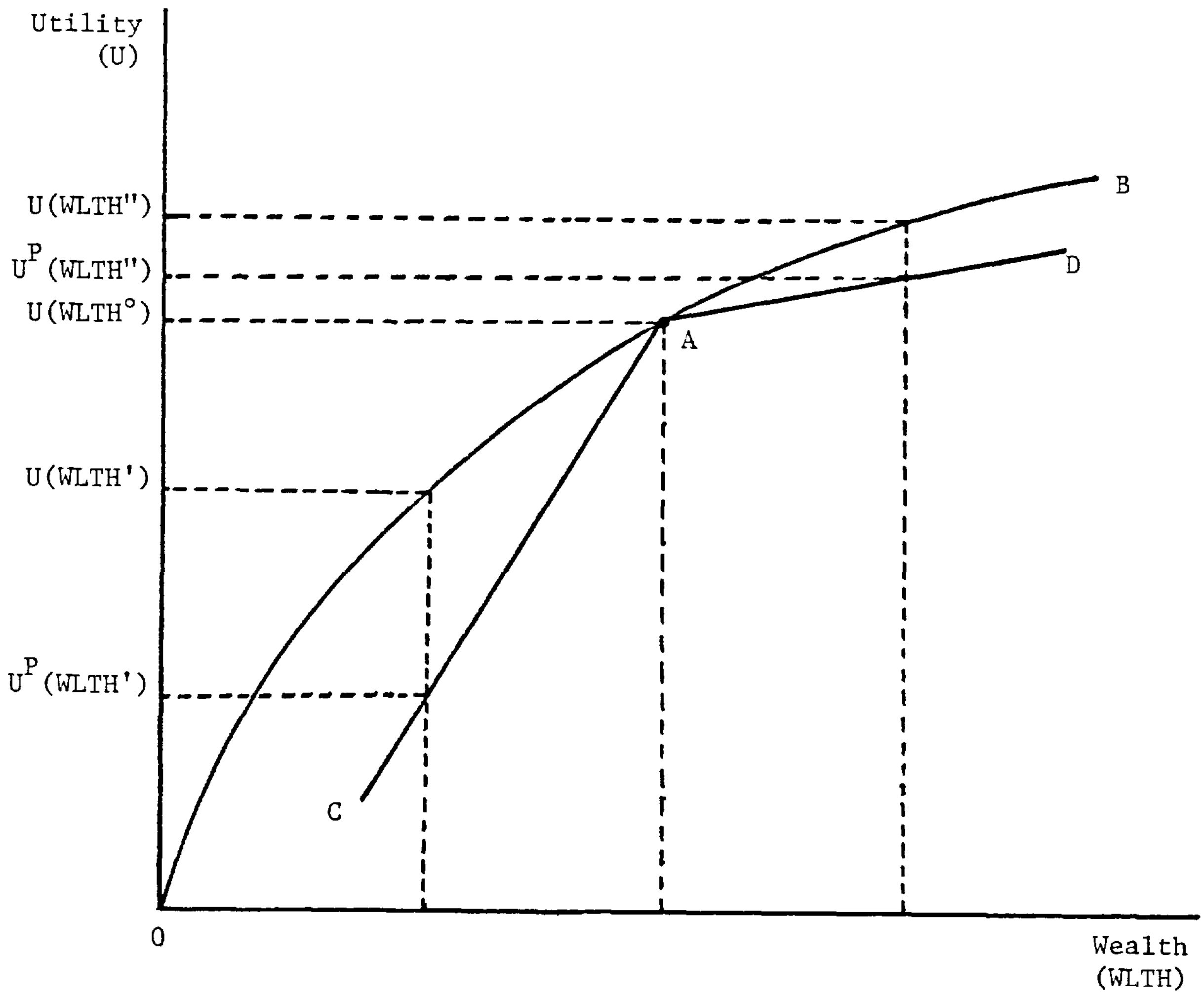
If we assume that the individual correctly calculates the change in utility that results from a small change in wealth, then their MVS (evaluated at $WLTH^\circ$) is the same for both gains and losses in wealth; that is:

$$MVS = \frac{U(WLTH^\circ)}{(1 - \pi^\circ)U'(WLTH^\circ)} = \frac{\Delta WLTH}{\Delta\pi} \tag{13}$$

where $U'(WLTH^\circ)$ is the same whether we are moving to the right (+) or to the left (-) of $WITH^\circ$. Therefore, MVS is the same for both small positive changes in WLTH and π (i.e., WTP) or small negative changes in WLTH and π (i.e., WTA) Hence, WTA = WTP.

On the other hand, if we assume that gains from wealth increases are underestimated while losses from wealth reductions are overestimated, the individual evaluates changes in wealth along the perceived utility function CAD in Figure 2.6. For a potential loss in wealth ($WLTH^\circ$ to WLTH') the resulting utility level is ex ante perceived to fall to U^{p}'(WLTH'): an overestimate of the true loss in utility (i.e., $U(WLTH^\circ)$ to U(WLTH')). On the other hand, for potential gains in wealth ($WLTH^\circ$ to WLTH") Figure 2.6 shows the individual underestimates the resulting gains in utility.

Figure 2.6: Valuation of Losses and Gains



For small changes in wealth, movements along the perceived utility function suggest that an increase in WLTH° does not render the same marginal utility, $U'(WLTH°)^{+}$, as decreases in WLTH°, $U'(WLTH°)^{-}$. Specifically,

$$U'(WLTH°)^{+} = \text{slope of } \overline{AD} < U'(WLTH°)^{-} = \text{slope of } \overline{AC} \qquad (14)$$

Assuming this conservative type of behavior, it is easily shown that WTA will be greater than WTP. For a potential. one unit reduction in risk, $\Delta\pi(-)$, an individual's WTP is described by $\Delta WLTH(-)$ in equation (15). Conversely, for a one unit increase in risk, $\Delta\pi(+)$, WTA is shown to be $\Delta WLTH(+)$ in equation (16).

$$\frac{U(WLTH°)}{(1-\pi°)U'(WLTH°)^{-}} = \frac{\Delta WLTH(-)}{\Delta\pi(-)} \qquad (15)$$

$$\frac{U(WLTH°)}{(1-\pi°)U'(WLTH°)^{+}} = \frac{\Delta WLTH(+)}{\Delta\pi(+)} \qquad (16)$$

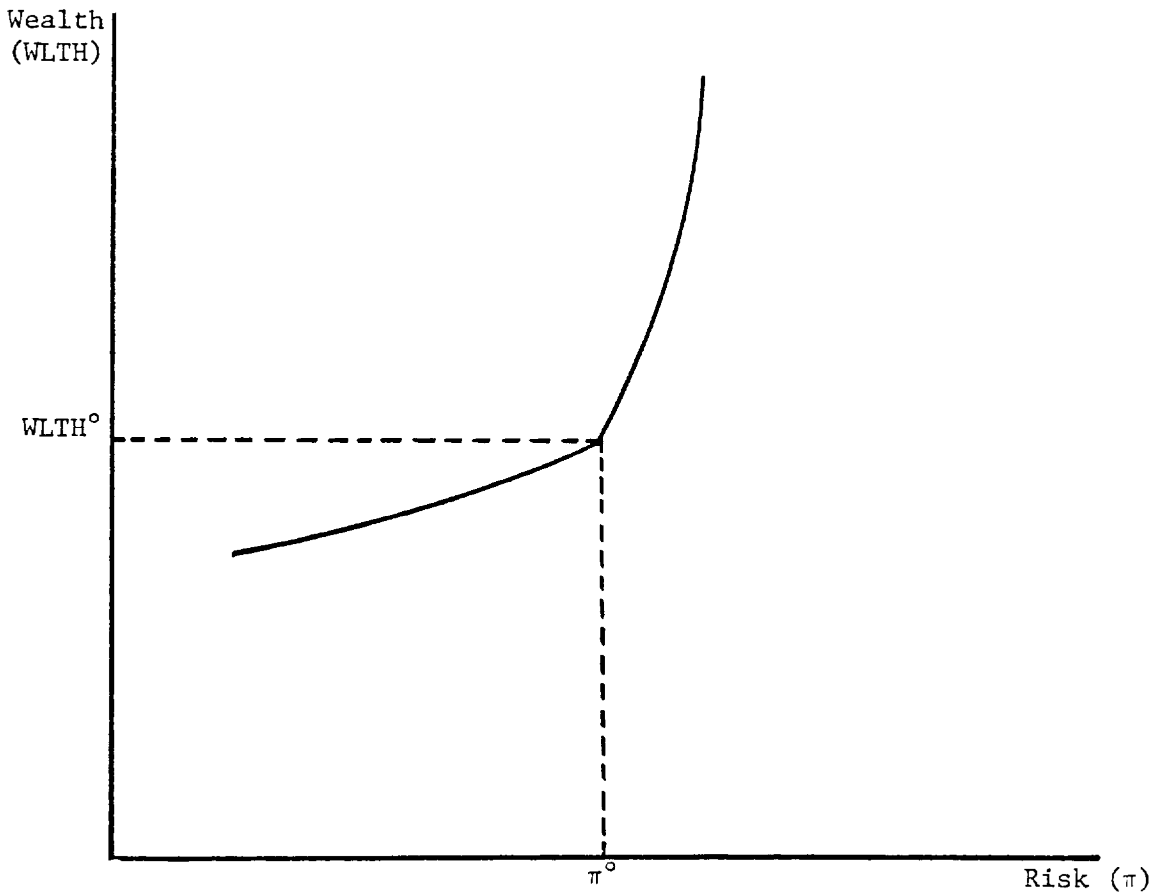
Since $U'(WLTH°)^{-}$ is greater than $U'(WLTH°)^{+}$, the left-hand-side of (16) is larger than the left-hand-side of (15). Moreover, since both $\Delta\pi(-)$ in (15) and An(+) in (16) are equal to one unit, it follows that $\Delta WLTH(-) < \Delta WLTH(+)$; that is, WTA is hypothesized to be large than WTP.

The effect of this difference between WTA and WTP is to put a "kink" in the individual's indifference curve between risk and wealth. Figure 2.7 shows that this kink occurs at the initial level of risk and wealth ($\pi°$ and WLTH° respectively). This figure shows that for an increase in risk from $\pi°$ the individual's MVS sharply increases which is associated with the relatively large compensation required (WTA large). Conversely, for a decrease in risk from $\pi°$ their MVS slowly decreases due to the relatively small compensation required (small WTP).

Recall that above it was stated that relatively steep indifference curves are suggestive of risk-averse behavior while relatively flat indifference curves are suggestive of risk-loving (or less risk-averse) behavior. Therefore, in the realm of safety evaluation, it can also be concluded that divergencies between WTA and WTP are associated with higher risk-averse preferences for deductions in safety (increases in π) while increases in safety (decreases in π) are associated with less risk-averse preferences.

If the above conservative process is repeated through trial and error, differences between WTP and WTA may eventually converge. Results in experimental economics are suggestive of this phenomenon. Coursey, Hovis, and Schulze (1985) found that in an experimental auction type situation for an environmental "bad," WTA and WTP measures were statistically similar after a number of trials. These same measures were significantly different, however, at the beginning of the experiment.

Figure 2.7: Indifference Curve Between Risk and Wealth



In summary, different behavior towards losses and gains in wealth may help to explain divergencies between WTA and WTP. Such behavior is conservative in nature and involves over-estimating changes in utility from losses in wealth and underestimating changes in utility which result from gains in wealth. This suggests that individuals exhibit conservative behavior when exploring areas of their utility functions that deviate from the norm or "status-quo." With time, however, through repeated experience with other areas of utility people may be able to accurately calculate ex ante the gains or losses from deviating from the norm. Therefore, this conservative tendency might be alleviated after repeated experiences with situations that deviate from the status-quo. Further, as norms change, a fairly accurate mental mapping of the utility function may result.

2.4.2. Voluntary and Involuntary Risk Acceptance

It has been shown that individuals have different evaluations for different types of risk. On the most general level, exposure to risk can be categorized as being either voluntary (e.g., risks associated with rock-climbing) or involuntary (e.g., risks associated with public transportation).

In situations of voluntary risk exposure, the individual evaluates the tradeoffs involved and can make a decision whether exposure to the risk is worthwhile: in short, they have control over the situation. Involuntary risk, on the other hand, is imposed on the individual by someone or something, and therefore, evaluation of the tradeoffs involved are outside his control.

Starr (1969) shows that individuals seem to be more averse towards involuntary than voluntary risk and, therefore, would require a higher level of compensation, if such compensation is available, for being exposed to the former. The fact, for example, that more of society's resources are devoted to airline safety than automobile safety is suggestive of this.

The reasons behind the differences in voluntary and involuntary risk evaluation is perhaps founded in ethics. Individuals are more sensitive to activities which are imposed on them by others than they are to activities they freely choose to engage in. It is felt, for example, that exposure to a drunken driver is "wrong" and no compensation is high enough to accept such risk. On the other hand, voluntarily exposing oneself to risk, as long as there are no external effects imposed on others, is viewed as an individual right.

It may be that questions attempting to elicit a willingness to pay measure trigger an ethical system associated with voluntary risk while those that attempt to elicit a willingness to accept are associated with involuntary risk valuation. This being the case WTA estimates would be expected to exceed estimates of WTP.

2.5 THE DETERMINANTS OF THE DEMAND FOR SAFETY

Estimation procedures which attempt to estimate an individual's subjective MVS afford economists the opportunity to approximate an indifference curve such as the one in Figure 2.1. From this, one can plot the relationship between MVS and risk which essentially will look the same as Figure 2.1: with MVS approaching infinity as π approaches one. This relationship can be viewed as the demand for safety.

The various studies discussed above all attempt to estimate "the" marginal value of safety. Given that the MVS estimates vary greatly across studies, it might be natural to ask which estimate better reflects the value of an expected life saved. Viewing the problem in this manner, however, may not be appropriate for policy purposes.

Economic theory and empirical evidence suggest that there is no reason to expect the MVS to be the same for all individuals or in all circumstances. In particular, an individual's MVS depends on their personal characteristics and the nature of the risk involved.[27] Therefore, as Viscusi (1978b) points out, "[e]mpirical analyses should not be directed at estimating an elusive value of life number; rather they should estimate the schedule of values for the entire population." For policy purposes it may be necessary to estimate MVS curves which show how safety valuations vary across personal characteristics. Once the group which will be affected by a safety program is identified and their socio-economic characteristics are known, the analysis of MVS curves is crucial in obtaining the appropriate MVS estimate to be used in policymaking.

In Section 2.1 it was shown that initial levels of risk and wealth as well as preferences towards risk in general will affect an individual's MVS. The latter may partially be captured by including age as a determinant of safety evaluation. The results of the model in Chapter 3 are suggestive of this in that people are found to be more risk averse as they get older.

With respect to other factors that may influence an individual's MVS, Viscusi (1978b) shows that education is an extremely significant determinant in the evaluation of safety. Moreover, Olson (1981) found union membership to affect worker's valuations of changes in job-related risk. One explanation given for this is that unions supply their members with better information regarding risk on the job.

Furthermore, Thaler and Rosen (1975) hypothesize that marital status and race play a big part in MVS estimates. They suggest that one would expect a married individual to have a relatively high MVS since included in this person's valuation is the external benefits incurred by dependents in having the individual alive. Thaler and Rosen suggest that race is an important factor in market wage-risk premiums. Non-whites, for example, may face discrimination in the risk-premiums they receive; thus, one could, by appealing to hedonic studies, erroneously conclude that non-whites have lower marginal values of safety in general. Other factors which may affect an individual's MVS include sex and initial health status. For example

Cropper (1977) and Pliskin et al. (1980) set up dynamic utility models which suggest that an individual's current health state affects his valuation of reductions in risk.

In addition to personal characteristics, the nature of the risk involved is an important factor in evaluating the benefits from safety improvements. This was discussed in some detail in Sections 2.2.3 and 2.2. In addition to the research discussed in these sections, Litai (1980) developed risk conversion factors to compare different types of risk. Table 2.2 summarizes the results obtained by Litai. This table shows a distinct difference in the evaluation of different risk types.

In summary, the quest of a single "correct" MVS estimate may not be very useful for evaluating the benefits of environmental safety programs. Instead research in this area would better directed towards estimating the way in which safety evaluations are related to personal characteristics and how these values change with various types of risk. This research specifically will address the former. The results of the survey described in Chapter 4 will be used to characterize individual's marginal valuations of safety by personal characteristics. These results are included in Chapter 5.

2.6 THE EXPECTED UTILITY MODEL

In Section 2.1 it was shown that the economics of safety is an application of expected utility (EU) theory. The EU model is a specific example of the general area known as holistic choice theory.[28] This general view of human behavior assumes that individuals are able to comprehensively compare all dimensions of potential alternatives, assign each a separate level of utility and therefore choose the combination which renders the most satisfaction. In the case of EU theory individuals must also calculate subjective probabilities of each state in the same holistic fashion. By analyzing the entire situation before making a choice, individuals should exhibit cognitive consistency.[29]

There is, however, some evidence that suggests individuals to be "irrational" when faced with decisions involving uncertainty. Research in this area reveals that psychological phenomena account for these seemingly irrational choices. In general it is felt that individuals lack the cognitive abilities to make the comprehensive decisions implied by EU maximization. In his survey article on EU theory, Schoemaker (1982) makes the following conclusions:

> As a descriptive model seeking insight into how decisions are made, EU theory fails on at least three counts. First, people do not structure problems as holistically and comprehensively as EU theory suggests. Second they do not process information, especially probabilities, according to the EU rule. Finally, EU theory, as an "as if" model, poorly predicts choice behavior in laboratory situations. Hence it is doubtful that EU theory should or could serve as a general descriptive model.

TABLE 2.2

RISK CONVERSION FACTORS

Risk Characteristics	RCF Estimated*	Probable Error Factor
Delayed/Immediate	30	10
Necessary/Luxury	1	10
Ordinary/Catastrophic	30	10
Natural/Man-made	20	10
Voluntary/Involuntary	100	10
Controllable/Uncontrollable	5	10
Occasional/Continuous	1	10
Old/New	10	10

*These mean, for example, that immediate risks require 30 times more compensation than delayed risks.

Schoemaker, therefore, concludes that the EU model, while being "the major paradigm in decision making [theory] since the Second World War," falls short of being used either descriptively to model decisions under uncertainty or positively to predict such behavior.

While Schoemaker's survey article offers an extremely comprehensive summary of the psychological reasons for such a conclusion, this section will highlight four major phenomena. They are: (1) context effects, (2) certainty effects, (3) problems in evaluating small probabilities of large events, and (4) bounded rationality.

2.6.1. <u>Context Effects</u>

"Since EU theory focuses on the underlying structure of choices, as modeled by 'rational' outside observers, it is largely insensitive to . . . contextual differences."[30] Empirical evidence suggests, however, that "the utility assigned an outcome can be influenced by the lottery context in which the outcome is embedded."[31] Context effects arise when the same alternatives are evaluated in relation to different points of reference resulting in an apparent reversal of preferences.

Kahneman and Tversky (1982) observed such a phenomenon when a large number of physicians were asked to imagine a situation in which a rare Asian disease is expected to kill 600 people. Two groups of 169 physicians were asked to make a choice between two alternative programs. While the results of the two programs were objectively the same for each group, the alternatives were framed differently, i.e., the context differed. The choices facing the two groups were as follows:

<u>Group I</u>

A: if program A is adopted exactly 200 people will be saved

B: if program B is adopted, there is a 1/3 probability that 600 people will be saved, and a 2/3 probability that no one will be saved

<u>Group II</u>

A: if program A is adopted exactly 400 people will die

B: if program B is adopted there is a 1/3 probability that nobody will die and a 2/3 probability that 600 people will die.

In both groups, program A will render 200 people saved with certainty while program B has an expected number of lives saved equal to 200. However, while 76 percent of the physicians in group I opted for program A (exhibiting risk-averse preferences), only 13 percent of Group II preferred that same program (exhibiting risk-loving preferences). Kahneman and Tversky explain this reversal of preferences by the difference in reference points. In Group I, "the death of 600 people is the normal reference point and the outcomes are evaluated as gains (lives saved)"; while in the second group "no deaths is the normal reference point and the programs are evaluated in terms of lives lost." Such reversals are in violation of EU theory which suggests that, by comprehensively evaluating the different choices, the context should not matter.

2.6.2. Certainty Effects

In their 1979 article, Kahneman and Tversky develop what they call prospect theory. This theory suggests that individuals weigh payoffs obtained with certainty disproportionately large relative to outcomes that are uncertain.

The EU axiom which assumes invariance of preference between certainty and risk, ceteris paribus, will be violated by the existence of such a certainty effect.[32] Schoemaker (1982) offers experimental results of the following two-choice situations:

Situation I: (IA) a certain loss of $45

(IB) a .5 chance of losing $100 and a .5 chance of losing $0

Situation II: (IIA) a .10 chance of losing $45 and a .9 chance of losing $0

(IIB) a .05 chance of losing $100 and a .95 chance of losing $0

In this experiment, the subjects' preferred (IIA) to (IA) while (IB) was preferred to (IIB). This violates EU since "the former implies that $U(-45) < .5U(-100) + .5U(0)$, whereas the latter preference implies the reverse inequality."[33]

2.6.3. Evaluating Small Probabilities of Large Events

Schoemaker (1982) makes the point that individuals do not behave as if they are maximizing EU for low-probability, high-loss events. Interviewing 2,000 homeowners in flood plains and 1,000 homeowners in earthquake areas, Kunreuther et al. (1978) found that of those who were informed on the availability of insurance against these hazards, many acted contrary to subjective EU maximization.[34] These results seriously question an individual's ability to process information on low-probability, high-loss events.

Schelling (1968) relates this cognitive difficulty to safety valuations. He notes that:

> A difficulty about death, especially a minor risk of death, is that people have to deal with a minute probability of an awesome event, and may be poor at finding a way--by intellect, imagination, or analogy--to explore what the saving is worth to them. This is true whether they are confronted by a questionnaire or a market decision

...The smallness of the probability is itself a hard thing to come to grips with especially when the increment in question is even smaller than the original risk. At the same time, the death itself is a large event, and until the person has some way of comparing death with other losses it is difficult or impossible to do anything with it probabalistically, even if one is quite willing to manipulate probabilities.

Individuals may deal with these problems in cognition by choosing to ignore such risk (i.e., "risk-denial"); or, they may rationalize the level of risk they accept through a phenomena which is referred to as cognitive dissonance. Akerlof and Dickens (1982) describe the latter phenomena by noting that "most cognitive dissonance reactions stem from people's view of themselves as 'smart, nice people.' Information that conflicts with this image tends to be ignored, rejected, or accommodated by changes in other beliefs."

For example, a "smart" person may not choose to work in an unsafe place. If the worker continues to work in a dangerous job, he will try to reject the cognition that the job is dangerous. Such a rationalization will not only affect his perceptions of job-related risk, but also his evaluation of reduction in such risk.

It should be emphasized that just because people err in their perceptions of risk does not render the possibility of a violation of EU: Subjective EU maximization is not inconsistent with EU theory. Rather, that individuals may exhibit cognitive problems with evaluating small-probability, large-loss events at all may lead to violations of EU theory.

2.6.4. Bounded Rationality

The presumption made by EU theory that individuals take a holistic view towards utility maximization conflicts with various psychological principles of judgment and choice.[35] Further, Schoemaker (1982) suggests that the failure of EU theory to contain descriptive or predictive content stems from an inadequate recognition of these principles.

Underlying most of psychological theories on human behavior is "a general human tendency to seek cognitive simplification."[36] The bounded rationality view (Simon, 1955) of human behavior suggests that people may intend to act rationally but lack the mental capabilities to satisfy EU maximization, Schoemaker (1982) summarizes the bounded rationality view of behavior as being

...that of an information processing system which is narrow in its perception, sequential in its central processing, and severely limited in short-term memory capacity . . . This limited information processing capacity compels people to simplify even simple problems, and forces them to focus more on certain problem aspects than others (i.e., anchoring). Such adaptation implies sensitivity to the problem

> presentation [i.e., context] as well as the nature of the response requested.

Such a view of human behavior suggests that individuals may not approach the maximization problem in a comprehensive fashion; rather, it is "cognitively easier to compare alternatives on a piece-meal basis, i.e., one dimension at a time."[37] If this is the case, then a model which requires a "portfolio perspective" (Markowitz, 1952) may fail to describe or predict human behavior and may well conclude individuals to be irrational.

2.6.5. <u>In Defense of the EU Model</u>

Proponents of EU theory sometimes respond to the aforementioned criticisms by saying laboratory experiments tend to be "artificial" and that situations in the "real" world render different behavior. This section will not appeal to such a defense. "Behavior in the laboratory is as real as other forms of behavior."[38] Further, Vernon Smith (1976) notes that 'if economic theory is proposed as a general model of scarce resource allocation, it should apply to experimental settings as well.'

Rather than criticizing the results of experiments that suggest EU theory may fail, one only need to look at other experimental research which suggests EU theory may work well in a dynamic setting. Particularly, in situations where there is a market for risk (e.g., the insurance market or the labor market), repeated experience with market mechanisms may correct misperceptions and individual decision biases.[39] Moreover, after many trials and errors the individual may gather the information needed to make holistic decisions. As Cummings, Brookshire, and Schulze (1984) point out, "some positive evidence does exist in the experimental economics literature that the expected utility model may be satisfied asymptotically after many interactions." Specifically, Plott and Sunder (1982) found that:

> There seems to be no doubt that variables endogenous to the operation of these markets served to convey accurately the state of nature to otherwise uninformed agents. We can conclude that . . . maximization of expected utility . . . must be taken seriously as not universally misleading about the nature of human capabilities and markets.

Moreover, there is "real world" empirical evidence that suggests the EU model to work well. Brookshire, Thayer, Tschirhart, and Schulze (1985) tested an expected utility model of self insurance against low-probability, high-loss earthquake hazards. They conclude that:

> Households process probability information in a reasonably rational and accurate way and that, at least in a market situation with a well defined institutional mechanism, the expected utility model may perform well in predicting behavior.

In summary, the case of the so-called failure of the expected utility model is by no means open and shut. The evidence suggests, however, that in situations where there is no market-like feedback, cognitive difficulties may render EU maximization difficult. On the other hand in cases where market information can be processed, the individual, at least over time, may develop the cognitive abilities to act rationally as described by EU theory. Further, because there does exist an implicit market for job-related-risk, applying the EU model to this "commodity", and attempting to elicit evaluations of reductions in such risk, may well be within the bounds of appropriateness.

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1. See Bacharach (1977) p. 23.
2. Kahneman and Tversky (1979) p. 160.
3. Rosen (1974) p. 244.
4. Violette and Chestnut (1983) p. 3-2.
5. Ibid., p. 3-1.
6. Ibid., p. 2-1.
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8. Ibid., p. 2-2.
9. Ibid., p. 2-2.
10. Ibid., p. 2-3.
11. Cummings, Brookshire, and Schulze (1984) p. 1.
12. Ibid., p. 2.
13. This quote is attributed to Richard Bishop.
14. Freeman (1979) pp. 915-20.
15. This quote is attributed to Richard Bishop.
16. See Violette and Chestnut (1983) pp. 2-7 - 2-10.
17. Ibid.
18. Bodily (1980).
19. Violette and Chestnut (1983) p. 2-7.
20. Ibid., p. 2-3.
21. Pindyck and Rubinfeld (1981) p. 176-7.
22. Thaler and Rosen (1975) p. 288.

23. Mishan (1971) p. 695.

24. Freeman (1979) pp. 34-5.

25. Ibid.

26. The most common explanation centers around a significant income effect.

27. See Viscusi (1978b).

28. Schoemaker (1982) p. 530.

29. Ibid., p. 549.

30. Ibid., p. 547.

31. Ibid., p. 547.

32. Ibid., p. 543.

33. Ibid., p. 543

34. See also Hershey and Schoemaker (1980).

35. Schoemaker (1982) p. 548.

36. Ibid.

37. Ibid.

38. Ibid., p. 554.

39. Ibid., p. 553.